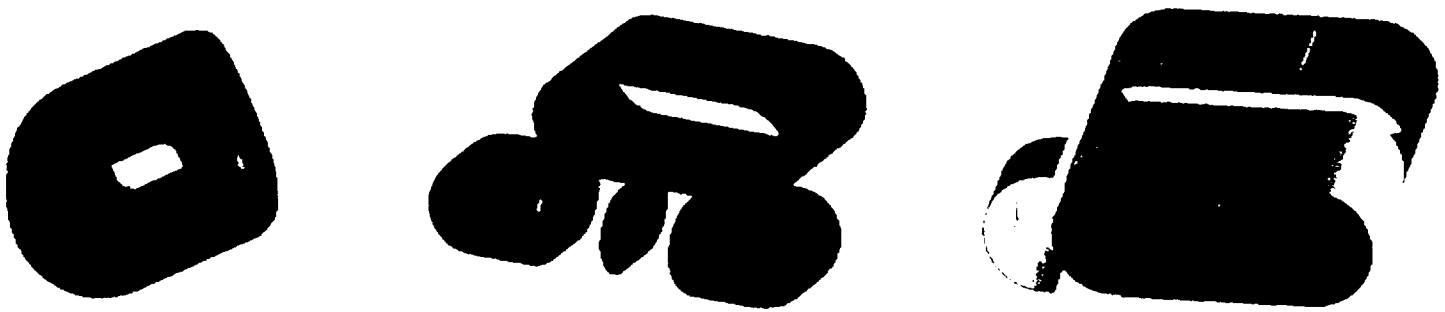
Thiokol Propulsion

Composite, Cryogenic, Conformal, Common Bulkhead, Aerogel-insulated Tank (CBAT)

Materials and Processing Methodologies



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September 19, 2000

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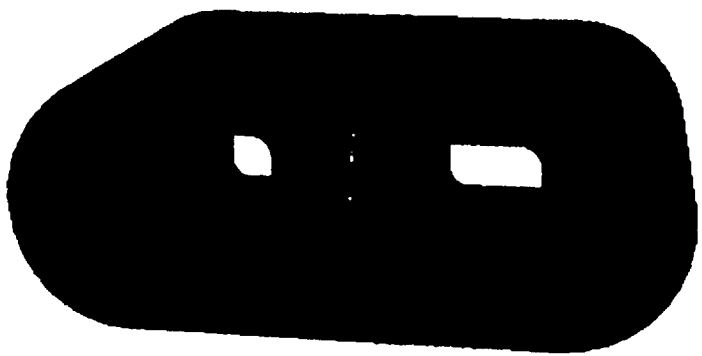
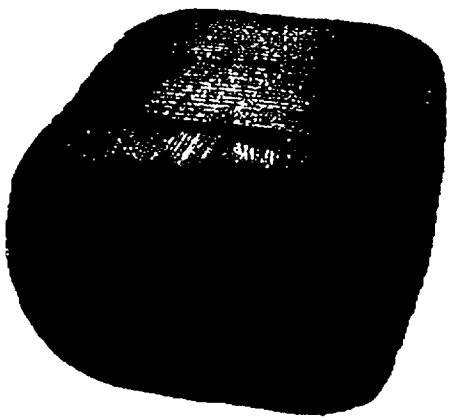
Agenda

- What is CBAT?
- Current Status
- Materials & Processes
  - Fabrication Method
  - Challenges
- Future Activities
- Summary

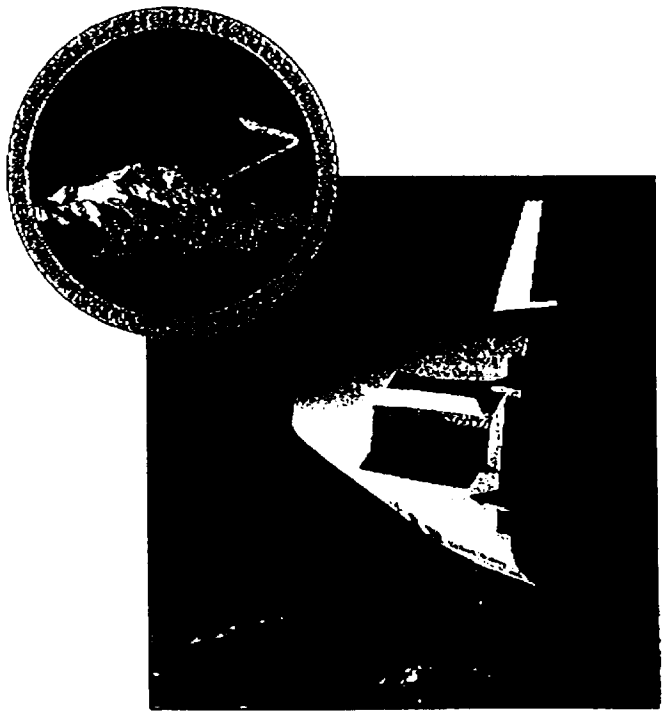




Introduction

What is CBAT?

- Program to evaluate new technologies for future generation Reusable Launch Vehicles (RLVs).
- Accomplished through:
  - Design
  - Fabrication
  - Testing of subscale system
- CBAT stands for:
  - Composite
  - Cryogenic
  - Conformal
  - Common Bulkhead
  - Aerogel-insulated
  - Tank



Introduction

CBAT - Composite

- **Composite refers to:**
  - Polymer Matrix Composites (PMCs) used in fabrication.
- **PMCs**
  - Materials of choice for most of today's aerospace applications.
  - High Strength/Stiffness
  - Low Density
  - As well as:
    - Resistant to fracture, corrosion, and wear.
    - Allow near net shape fabrication
    - Facilitate component integration
- **CBAT will use graphite/epoxy prepreg tow and fabric.**
  - Hexcel IM7 (12k and 5HS)
  - Cytec-Fiberite 977-2

Introduction

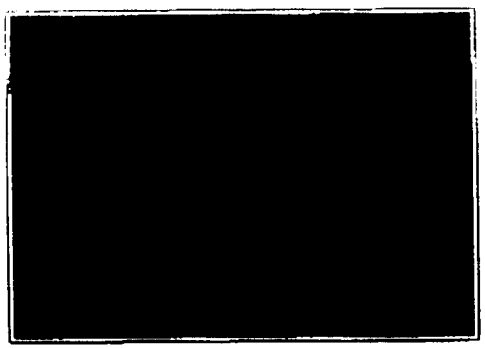
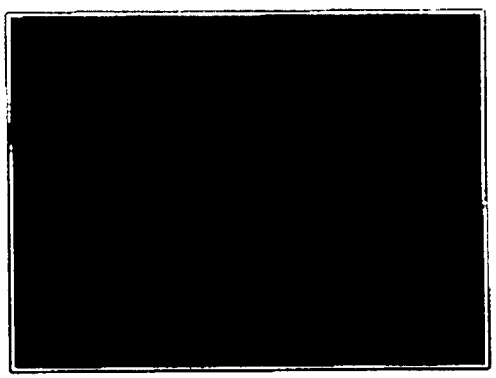
CBAT - Cryogenic

- **Cryogenic refers to:**
  - Prospective propellants for use with the system.
- **Cryogenic propellants**
  - High energy to mass
  - Challenges:
    - Reactivity
    - Thermally-induced strains
- **CBAT design is based on LOX/RP system.**
  - Testing will use LN_2 instead of LOX.
    - Increased Safety
    - Reduced Cost
  - RP may be replaced by LH_2.

Introduction

CBAT - Conformal

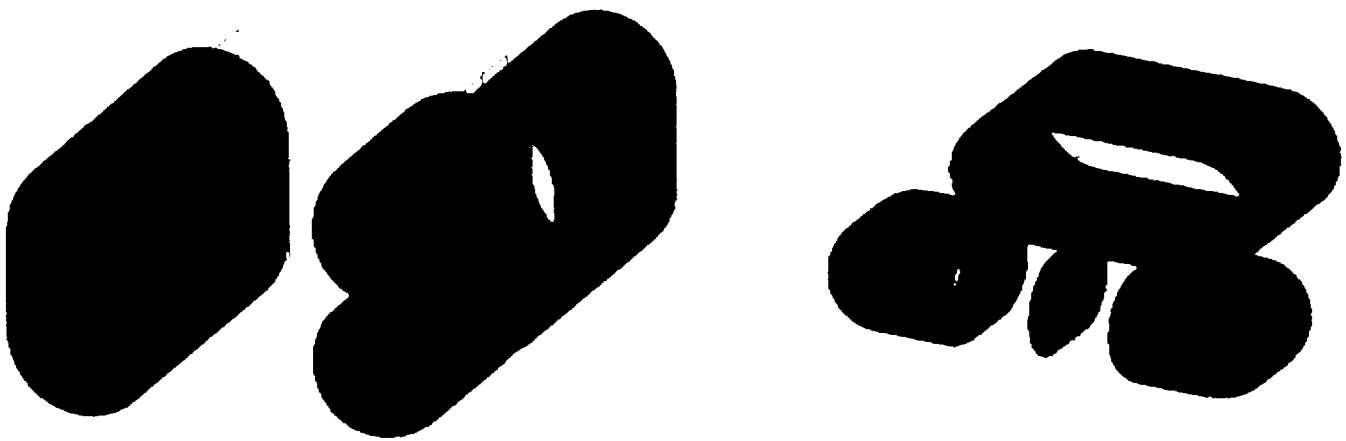
- **Conformal refers to:**
  - Capability to customize the propellant storage system to the shape of the vehicle it will be used in.
- **Conformal Storage Systems**
  - Maximize capacity
  - Facilitate integration into vehicle structure
- **CBAT design simulates a conformal-type system which could be used in conjunction with future generation RLVs.**


Introduction

CBAT - Common Bulkhead

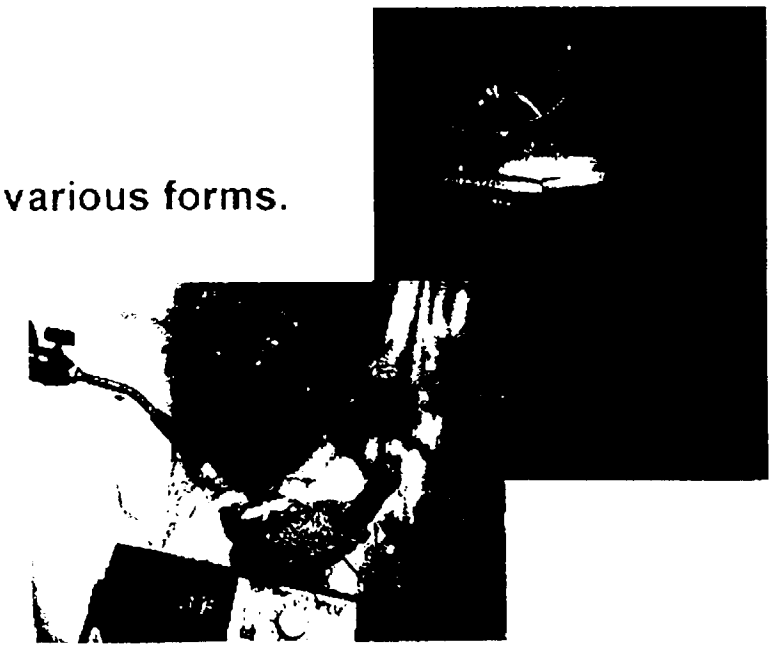
- **Common Bulkhead refers to:**
  - Geometry or methodology for placing/packaging the propellant storage tanks adjacent to one another within the vehicle
- **Common Bulkhead Propellant Storage Systems**
  - Reduce design restrictions
  - Maximize capacity
- **CBAT design simulates a conformal-type system which could be used in conjunction with future generation RLVs.**



Introduction

CBAT - Aerogel-insulated

- **Aerogel-insulated refers to:**
  - Use of a special class of materials to insulate around and between certain portions of the system.
- **Aerogels**
  - Low density
  - Low thermal conductivity
- **CBAT will potentially use aerogels in various forms.**
  - Particulate
    - Thermal blankets
    - Encapsulated packets
  - Monolithic



Current Status

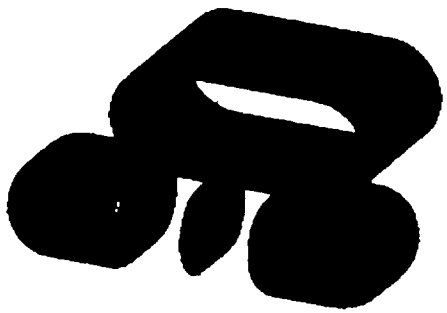
CBAT - Design, Fabrication, & Test

- **Design**
  - Incorporates each of the aforementioned technologies and/or functionalities.
  - Component form and fit have been verified using rapid prototyping.
    - Stereolithography Apparatus (SLA)
    - Laminated Object Manufacture (LOM)
- **Fabrication**
  - Fabrication of tooling, fixtures, and metal hardware is continuing.
  - Winding mandrel molding is complete (1st mandrel)
  - Material characterization and design verification specimens are being processed.
- **Test**
  - Material characterization testing started in April 2000.
  - Projected start of component testing is October 2000.

Materials & Processing

Fabrication Method

- Tanks will be fabricated using a combination of processes.
  - Filament Winding
    - Removable mandrel
  - Hand Lay-up
- Remaining components will be produced by hand lay-up.
- Adhesive will be used to bond the tanks, common bulkhead assembly, and skirt inner skin.
- Outer skin and core will be hand laid-up on the assembly and co-cured/bonded into place.



Materials & Processing

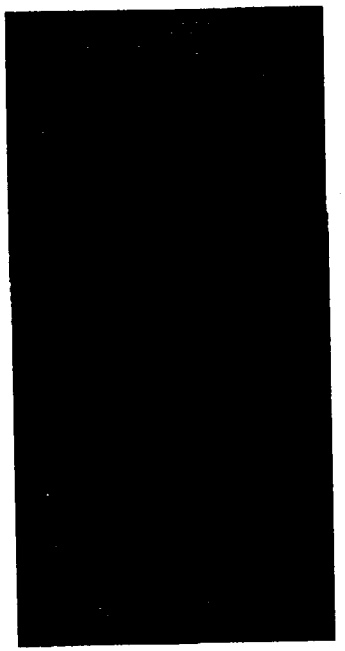
Challenges

- **Potential challenges addressed to date:**
  - Filament Winding
  - Hand Lay-up
  - Tooling
- **Remedied through use of:**
  - Subscale Models
  - Simulation
  - Test

Materials & Processing

Challenges - Filament Winding

- **Problem(s)**
  - Build-up in the dome regions.
  - Tow slippage.
- **Approach**
  - Evaluate wind options
    - Polar/Hoop
    - Helical
  - Wind subscale models (1/5 scale).
    - Use Rapid Prototyping for the mandrels.
  - Enhance Tack
    - Increase solvent content of tow.
    - Place film adhesive on mandrel prior to winding.



Materials & Processing

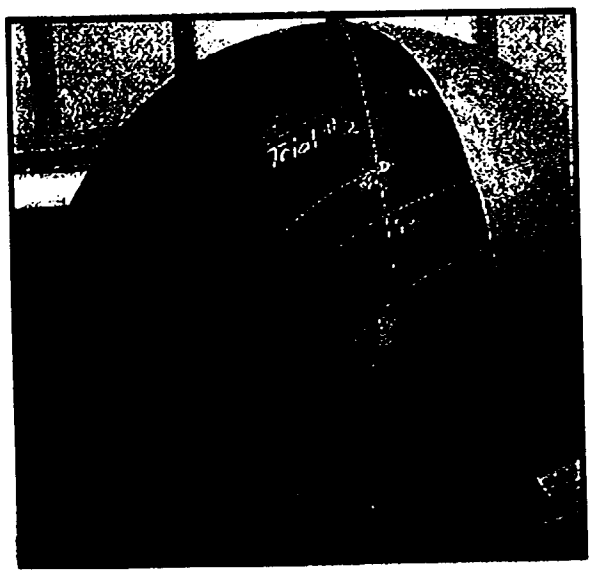
Challenges - Hand Lay-up

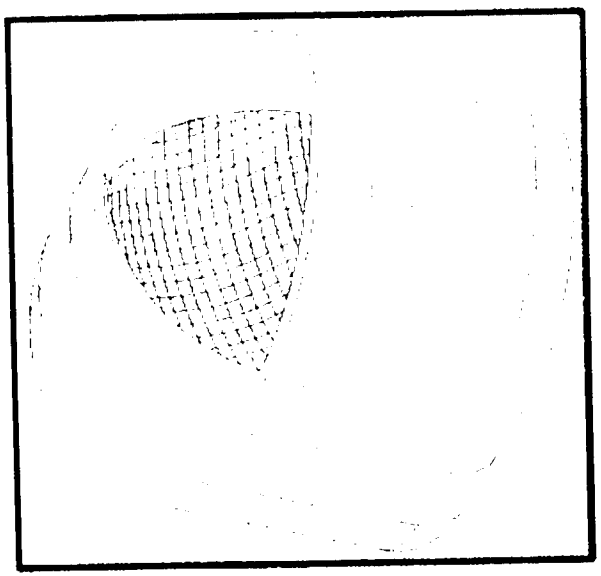
- **Problem(s)**
  - Lay-up of prepreg cloth in dome regions.
    - Fiber distortion
    - Wrinkling
- **Approach**
  - Drape testing
    - Quantify distortion
  - Simulation
    - Create ply patterns with minimal chance for wrinkling.
    - Factor fiber distortion into structural models.

Materials & Processing

Challenges - Hand Lay-up

- **Results**
  - Drape testing quantified distortion for use in simulation.
  - Simulation modeled plies
    - Generated ply patterns to minimize wrinkling and distortion
    - Provided fiber distortion data to feed into the structural model.

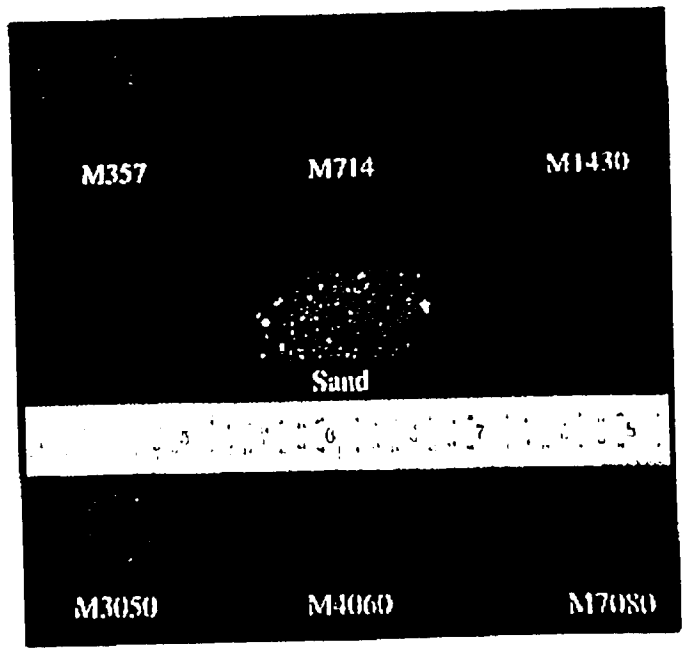




Materials & Processing

Challenges - Tooling

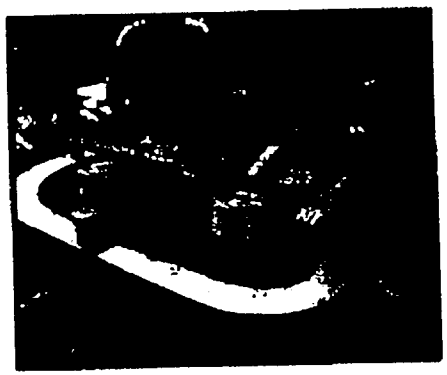
- **Problem(s)**
  - Previously used Macrolite™ binder incompatible with 350°F cure.
- **Approach**
  - Use sand mandrel binder, sodium silicate
    - Proven temperature capability.
  - Evaluate on subscale articles.
    - 5.75-inch mandrel
    - 18-inch wound vessel



Materials & Processing

Challenges - Tooling

- **Results**
  - Sodium silicate binder with orignal Macrolite™ formulation formed insoluble mandrel.
    - Fine particles enhanced packing, eliminated porosity, and prevented water intrusion during washout.
  - Replacement of finest Macrolite™ particles and alumina microspheres with sand, and minimization of the binder resulted in a mandrel with good washout characteristics.
    - 3% heavier than a mandrel made using original Macrolite™ formulation developed by Thiokol in Utah
    - 69% lighter than a mandrel made using sand



Future Activities

- **Near Term**
  - Fabrication
    - First Full Scale Winding (Tank Shell) for door test
      - Scheduled Completion - 9/29/00
    - Tie Down Skirt for door test
      - Scheduled Completion - 10/6/00
    - Two doors for door test
      - Scheduled Completion - 10/6/00
    - Second Full Scale Winding for sectioning and coupon testing.
      - Scheduled Completion - 11/10/00
  - Test
    - Full Scale Door Seal Test
      - Scheduled for 10/00

- **Long Term**
  - Fabricate and conduct cyclic testing of Full Tank System Assembly
    - Scheduled completion 9/01
  - Install tank system TPS and conduct LH_2/LN_2 structural test.
    - Scheduled completion 9/02

Summary

- **CBAT is in the process of Designing, Fabricating, and Testing a propellant storage system that will integrate various technologies and functionalities.**
  - Composites
  - Cryogenic propellants
  - Conformal shape
  - Common Bulkhead
  - Aerogel insulation
- **Program is still in the fabrication phase.**
- **Following completion of fabrication and test, concept could be incorporated into future generation RLVs.**
  - Improve performance and reliability
  - Reduce weight